

Dynamic of Selected Soil Matter and Biotic Activity of a Haplic Podzol under Pine (*Pinus sylvestris*) and Spruce (*Picea abies*) Northwest Germany

L. Beyer, H.-P. Blume, M. Peters, U. Irmler und B. Henß

Synopsis

Die Humus- und Stoffdynamik und die biologische Aktivität eines Eisen-Humus-Podsols wurde in den Jahren 1986 bis 1988 untersucht. Der stark versauerte Waldboden weist eine geringe biologische Aktivität mit schlechtem Streuumsatz und mit starker Humusakkumulation auf. Insbesondere Oribatiden und Dipterenlarven sind an der Bildung des feinhumusreichen Rohhumus beteiligt. Dieser ist Konsequenz der mangelnden Bioturbation, weil Regenwürmer fehlen. Der Podsol ist durch hohe Elementausträge aus dem Wurzelraum gekennzeichnet. Dies ist bei den Schwermetallen auf die Versauerung zurückzuführen. Eine rezente Podsolierung konnte durch die Untersuchung der Bodenlösung auf Kohlenstoff-, Eisen- und Aluminium nachgewiesen werden. Aluminium und Eisen lagen im Oberboden hauptsächlich in organischen Metall-Komplexen und im Unterboden als anorganische Spezies vor. Die Stickstoffzufuhr über die Niederschläge, die Stickstoffakkumulation im Humuskörper und der N-Austrag sind in zunehmendem Maß anthropogen verursacht.

Haplic Podzol, organic matter transformation, C-N-Al-Fe cycle, biotic activity, podzolization

1. Introduction

Fresh organic residues are decomposed in the soils and transformed into solid and soluble humic substances. In the forest soils organic matter transformations could be retarded due to a low pH and nutrient supply (MITCHELL & NAKAS 1986). The production of acids during podzolization and the anthropogenic input of acidic compounds (KREUTZER 1989) reduces the activity of soil fauna and microflora (SCHULZE & al. 1989). In a sandy Haplic Podzol under Pine and Spruce in Northwest Germany morphological features indicate podzolization (BLUME 1986). The intention of this paper is to verify recent soil degradation by acidic soil compounds, humus accumulation and translocation as well as metal and nitrogen output by means of investigations of humus, water- and C-N-Al-Fe-dynamics, biotic activity and soil fauna.

2. Site and Method

2.1 Site

A sandy Haplic Podzol in the Holsteinische Vorgeest (Precipitation 750 mm, annual mean temperature 8.3°C) was investigated. Selected soil properties are presented in Tab. 1. The Pine (*Pinus sylvestris*) and Spruce (*Picea abies*) forest was planted at the end of the last century after the heather vegetation had been burnt. The strongly acidified soil is characterized by a thick organic layer (Fig. 1). About 50% of the soil carbon is accumulated in the O-horizons. This is why most of the soil fauna lives in this organic layer (Fig. 2). Earthworms, which dig in deeper horizons are of minor importance in this soil (Fig. 2). The Bh as a sink of humic compounds is typical for this soil type (Fig. 1).

2.2 Methods

All soil properties (Tab. 1) were determined according to SCHLICHTING & BLUME (1966). Soil organic matter (SOM) composition was determined with a wet chemical extraction procedure (BEYER & BLUME 1990). Soil fauna was estimated as described by BEYER & IRMLER (1991). From June 1986 to May 1988 the dynamics of water, elements and microbial activity were measured every fortnight. The soil solution was extracted by centrifugation. All carbon fractions were determined by dry combustion (C-Analyzer, Fa. Ströhlein) and all N-fractions by using a Flow-Injection-Analyzer (Fa. Tecator). Al, Fe and Ca were determined with an AAS (Per-

kin Elmer 5000*HGA 500). The fractionation of aqueous Al and Fe was executed with a cation exchanger (Amberlite IR-120, Fa. Serva) according to DRISCOLL (1984). Soil respiration was calculated with a modified Lundegardh procedure (ANDERSON 1982). The degradation of buried cellulose was observed according to UNGER (1960). Thermal supply was estimated using the temperature (BEYER & SIBBESSEN, 1991) and heat capacity of soil matter; H₂O-supply and balance using the water tension and input with the aid of VAN GENUCHTEN's model (1980). The ion balances were calculated with the aid of the water balance and the ion concentrations in the soil solution. For detailed information of cycles, balances and all methods see BEYER (1989) and PETERS (1991).

Tab. 1: Properties of a sandy Haplic Podzol under pine and spruce in the Segeberger Forst.

horizon	depth cm	bulk dens.	pH CaCl ₂	Ca mmol _c kg ⁻¹	K	Mg	Na	H+Al mmol _c kg ⁻¹	BS %	Fe _d -- mg*g ⁻¹ --	Fe _o -- mg*g ⁻¹ --	C _{org} %	N _t %	C/N	HA/FA
L	15-13	0.03	3.5	85	11	18	5	166	24	nd	nd	50.8	1.45	41	1.25
Of	13-7	0.16	3.0	93	5	22	4	585	12	nd	nd	45.5	1.65	28	2.11
Oh	7-0	0.21	2.6	83	5	18	5	680	10	nd	nd	35.2	1.42	25	1.94
Aeh	0-10	0.81	2.7	22	3	5	2	156	11	0.6	0.5	7.6	0.46	16	1.58
Ahe	-20	1.54	3.1	2	1	1	1	13	25	0.1	0.1	1.3	0.05	25	1.33
Bh	-25	1.37	3.1	7	0		2	279	3	1.8	1.8	8.0	0.23	35	0.70
Bhs	-30	1.37	4.0	1	0	0	0	141	1	9.7	6.3	2.4	0.09	26	0.33
CBvs	-70	1.59	4.5	1	0	0	0	26	3	0.6	0.2	1.0	0.03	40	0.34
GCv	-160	1.59	4.7	1	0	0	0	13	6	nd	nd	0.1	0.01	10	nd

bulk dens.: bulk density in g*cm⁻³, Ca, Mg, Na, H+Al in NH₄Cl. BS: base-saturation per centage in % of CEC, Fe_d: dithionite soluble iron, Fe_o: oxalate soluble iron, C_{org}: organic carbon after dry combustion, N_t: total nitrogen after Kjehldahl-Extraction, HA: humic acids, FA: fulvic acids after NaOH-Extraction, nd: not determined.

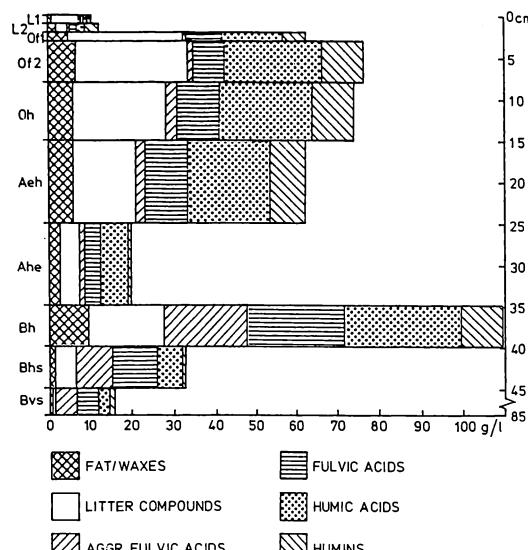
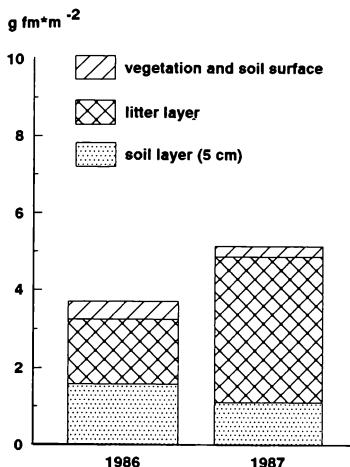


Fig. 1: Composition and Distribution of Soil Organic Matter in a Haplic Podzol under Pine (*Pinus sylvestris*) and Spruce (*Picea abies*) in Northwest Germany (in g soil⁻¹).



animal group	$\text{mg dm}^{-2} \text{m}^{-2}$	
	1986	1987
Collembola	74	57
Oribatei	135	260
Lumbricidae	36	12
Enchytraeidae	25	4
Diptera larv.	3	22
Tipulidae larv.	22	284
Gastropoda		8

Fig. 2: Composition and Distribution of Soil Fauna in a Haplic Podzol up to a depth of 50 cm in the Segeberger Forst, Northwest Germany (fm: fresh mass, dm: dry mass).

3. Results and Interpretation

The main rainfall occurred in winter giving rise to the peak of N-input (Fig. 3). In this sandy soil oxygen was never a minimum factor, because the air volume was always >15%. Shortage of water never took place probably due to precipitation of approximately 800 mm and the high water capacity of the organic layer. The water supply was high enough with $\geq 100 \text{ l m}^{-2}$ (Fig. 3: H_2O). A strong correlation between litter fall and the thickness of the litter layer (L-horizon) was observed during the vegetation period. This large food supply immediately stimulated the soil fauna (see Fig. 3). Especially in the year 1987 and after mechanical decomposition and/or digestion by soil animals, CO_2 was released by microorganisms (Fig. 3: Resp) by degrading cellulose (Cel), which is the main part of litter (SZEGI 1988). C-supply in the soil solution was correlated with microbial activity ($r_{\text{CO}_2 \cdot \text{C}} = 0.75^{***}$, $r_{\text{Cel} \cdot \text{C}} = 0.52^{**}$, $n=24$). At the next step of SOM turnover nitrogen was released, especially in autumn and winter. The N-supply was also stimulated by the N-input with rainfall. Microorganism activity was strongly correlated with thermal supply (see Fig. 3).

In the Podzol the interactions between litter supply, mass of soil fauna, microbial activity, C- and N-release could be shown well, although SOM transformation was at the end of the possible range in Northwest Germany (BEYER 1990). Two years after litter fall only 50% of the fresh plant material had been broken down (Fig. 4). A large organic layer had developed (Tab. 1, Fig. 1). Its formation could be reconstructed by an investigation of the carbon cycle. The carbon surplus was about $90 \text{ g C m}^{-2} \text{ a}^{-1}$ (assuming that according to ANDERSON (1982) root respiration is 20% of total respiration). The large organic layer contained about 10 kg C m^{-2} (Tab. 2). That means a formation time about 100 years, which was similar to the age of the stand (see Sites and Methods).

On the other hand the Haplic Podzol under Pine and Spruce was characterized by a very high carbon translocation into the Bh (Tab. 3). More than 50% of the soluble carbon of the leaching soil solution was fixed in the B-horizons (Tab. 3) and the development of the carbon sink probably was still going on (Fig. 1). Especially the mobile, aggressive fulvic acids were translocated from the organic layer (Of, Oh) and the topsoil into the subsoil (Tab. 1: HA:FA). This was connected with a metal transfer, especially Al (Tab. 3). The amount of iron was much smaller (Tab. 3 + 4), because the parent material contained little iron (BLUME 1986). Aluminium was released from the silicates in large amounts (ULRICH & SUMNER 1991) and translocated independent of SOM matter and podzolization as anorganic Al-species (Tab. 3+4), because of the very low pH. In the topsoil most of the inorganic Al-species were toxic Al^{3+} (Tab. 4). The concentration of total aluminium in the soil solution was $\geq 6.7 \text{ mg l}^{-1}$ and the $\text{Ca}^{2+}/\text{Al}^{3+}$ -ratio ≤ 1 (Tab. 4). Both data indicate a strong phytotoxicity (ROST-SIEBERT 1985). This reduced both: microbial activity and decomposition of organic matter (BEYER 1989). Neverthe-

less, total aluminium was much lower in the organic layer due to the lack of minerals (Tab. 1). Aluminium may also be partly fixed at the solid organic state (FRANK 1987). Most of the aluminium was fixed in alumino-organic complexes, NÄTSCHER & SCHWERTMANN (1985) found that the prevailing part of monomeric aluminium species are in reality small positively loaded complexes with the same properties at the exchanger as the ionic cations. The small amount of inorganic, toxic aluminium in the organic layer was probably the reason for the high rooting density in the Oh-horizon (ULRICH & al. 1979).

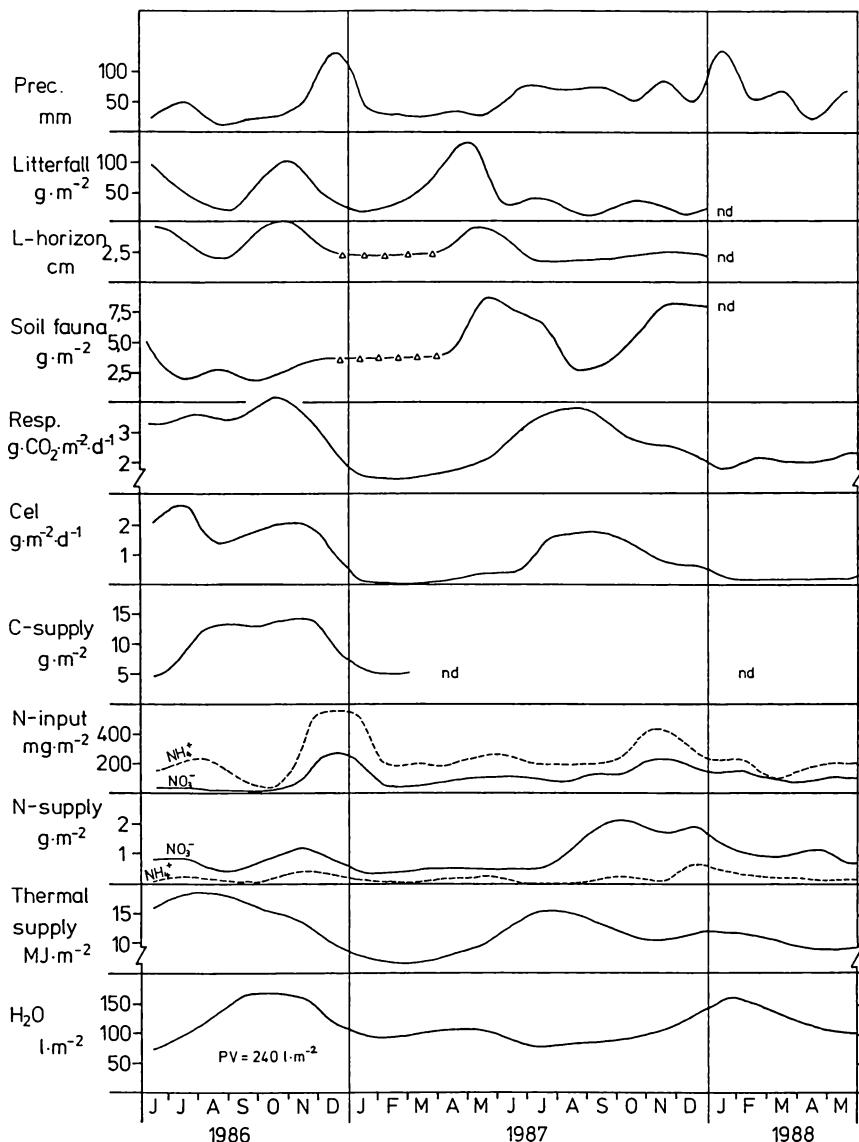


Fig. 3: Annual dynamic of selected environmental, chemical and biotic properties of a Haplic Podzol under Pine and Spruce in Northwest Germany (calculated soil depth 50 cm).

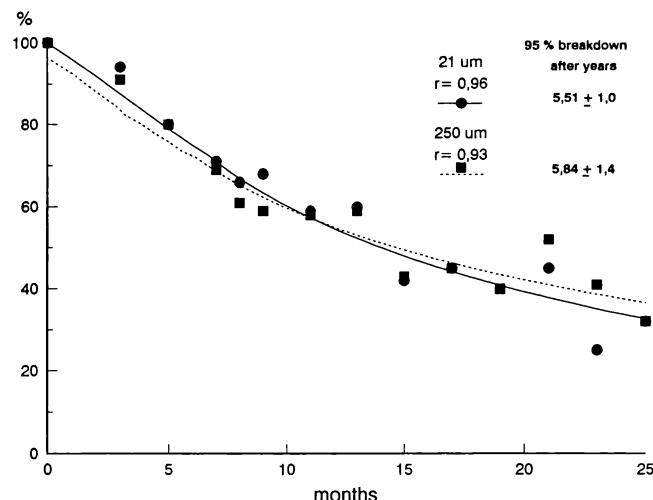


Fig. 4: Breakdown of litter (%) in a Pine (*Pinus sylvestris*) and Spruce (*Picea abies*) forest on a Haplic Podzol in the Segeberger Forst, Northwest Germany ($\pm x$: standard deviation, mesh size in μm).

Tab. 2: Mean annual carbon balance of a Haplic Podsol under pine and spruce in the Segeberger Forst.

C _{org}		C-Input				C-Output		
layer	0-30	precipi-	litter ¹	root	Σ	resp	leach.	∂
	$\text{g} \cdot \text{m}^{-2}$	ta-		residues	$\text{g} \cdot \text{m}^{-2} \cdot \text{a}^{-1}$			
9945	15937		18	271	45	334	279	28
layer: Amount of C _{org} in the organic layer, 0-30: Amount of C _{org} at a depth of 0-30 cm below soil surface, ¹ including necrotic soil vegetation, resp.: soil respiration, leach.: leaching water; ∂ = Output - Input.								

Tab. 3: Mean annual amounts of water, aluminium, iron and carbon (SOC) passing through a depth of 20 (a), 60 (b) and 150 cm (c).

Prec. mm^{-1}	water $\text{l} \cdot \text{m}^{-2} \cdot \text{a}^{-1}$			Al _{total} $\text{Al}_{\text{organic}}$ $\text{g} \cdot \text{m}^{-2} \cdot \text{a}^{-1}$			Fe _{total} $\text{Fe}_{\text{organic}}$ $\text{g} \cdot \text{m}^{-2} \cdot \text{a}^{-1}$			SOC $\text{g} \cdot \text{m}^{-2} \cdot \text{a}^{-1}$			$\text{NO}_3^- + \text{NH}_4^+ \cdot \text{N}$ $\text{g} \cdot \text{m}^{-2} \cdot \text{a}^{-1}$			
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	
April-Sep.	186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Oct.-March	594	319	289	264	3.1	6.4	4.4	0.3	0.4	1.0	28	12	6	4.7	3.5	2.9

¹ excluding interception, a: Aeh+Ahe, b: Bh+Bhs, c: CBvs

Tab. 4: Properties of the soil solution of a Haplic Podzol under pine and spruce.

hor.	pH	SOC	Fe_t	Fe_o	Fe_o % of Fe_t	Al_t	Al_o	Al_o % of Al_t	Al_{an}	Al^{3+}	Al^{3+} % of Al_{an}	Ca^{2+}	$\frac{Ca^{2+}}{Al^{3+}}$
		----- mg*l ⁻¹ -----				--mg*l ⁻¹ --			-- mg*l ⁻¹ --			mg*l ⁻¹	
L/O	3.33	nd	nd	nd	nd	0.9	0.6	64	nd	nd	nd	nd	nd
Aeh	3.17	94	1.0	0.6	58	8.9	2.2	25	6.8	6.6	98	6.0	0.9
CBvs	3.75	19	1.9	1.8	95	8.4	1.6	19	6.8	4.5	66	3.8	0.9
GCv	3.75	30	0.6	0.4	67	15.1	0.8	5	14.3	8.1	57	4.4	0.5

hor.: horizon, SOC: soluble organic carbon, Fe_t : total iron, Fe_o : ferro-organic iron, Al_t : total aluminium, Al_o : alumino-organic aluminium, Al_{an} : anorganic Al-species, Al^{3+} : calculated according NAIR & PRENZEL (1978), all data mean from April 1986 - March 1987.

Tab. 5: Real content (RC) of nitrogen and calcium of needles from the investigated site and limiting values (LV) in g*kg⁻¹ of dry matter.

	RC	LV
Nitrogen	20.7	14.0 -17.0 ¹
Potassium	3.9	5.0 -12.0 ²
Calcium	0.4	3.5 - 8.0 ²
Magnesium	0.6	1.0 - 2.5 ²
Sulfur	1.3	1.0 - 1.3 ²

¹acc. to FIEDLER & THAKUR (1984)
²acc. to BERGMANN (1986).

The low nutrient contents (Tab. 1: Ca, K, Mg, Na) not only affected the biological activity (index: soil respiration and cellulose degradation) and SOM decomposition. Ca-, K- and Mg-supply of the needles was insufficient too (Tab. 5). On the other hand there was no shortage of nitrogen and sulfur (Tab. 5). A sufficient N-supply and simultaneously an acidification of the soils had been repeatedly shown to be a typical phenomenon with regard to the recent forest decline (KREUTZER 1989). In Schleswig-Holstein in the Geest the nitrogen input (Fig. 3: $NH_4^+ >> NO_3^-$) is caused by the slurry management in this area (BLUME & al. 1989). This nitrogen did not only accumulate in the mineral topsoil (Tab. 1: C/N) as postulated by KREUTZER (1989), as in the investigated soil in the Segeberger Forst large amounts of nitrogen were translocated out of the rooting area in contrast to carbon (Tab. 3).

4. Conclusion

The strongly acidified Haplic Podzol under Pine (*Pinus sylvestris*) and Spruce (*Picea abies*) is characterized by a low biotic activity. This is why litter decomposition rates are low and humus is accumulated in the soil. Earthworms are of minor importance and no relocation by bioturbation could be observed in the soil and a thick organic layer has developed. Recent podzolization could be verified, as from the raw humus carbon (fulvic acids), nitrogen, Al and Fe have been translocated into the subsoil. Al and N may be a risk to groundwater.

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References

- ANDERSON, J. P. E., 1982: Soil respiration. - In: A. L. PAGE (ed.): Methods of Soil Analysis, 2. Chemical and Microbiological Properties. - Am. Soc. of Agron., Madison, WI: 831-871.
- BERGMANN, W., 1986: Farbatlas Ernährungsstörungen bei Kulturpflanzen. Fischer, Jena.
- BEYER, L., 1989: Nutzungseinfluß auf die Stoffdynamik schleswig-holsteinischer Böden-Humusdynamik und mikrobielle Aktivität. - Schriftenr. Inst. Pflanzenernähr. Bodenk. Uni Kiel 6.
- BEYER, L. & H.-P. BLUME, 1990: Eigenschaften und Entstehung der Humuskörper typischer Wald- und Ackerböden des Schleswig-Holsteins. - Z. Pflanzenernähr. Bodenk. 153: 61-68.
- BEYER, L., 1990: Standortsbewertung der biologischen Aktivität über Ermittlung der Bodenatmung und der zellulytischen Aktivität im Feld. - Z. Pflanzenernähr. Bodenk. 153: 261-269.
- BEYER, L. & E. SIBBESEN, 1991: Intersite Measurement of Mean Temperature by the Sucrose Inversion Method for Ecological Studies. - Comm. Soil Sci. and Plant Analysis 22 (1&2): 75-86.
- BEYER, L. & U. IRMLER, 1991: The Structure and the Dynamic of litter decomposition on a Luvisol and a Podzol under Forest. - Pedobiologia 35: 368-380.
- BLUME, H.-P., 1986 (Ed.): Soils and Landscapes in Schleswig-Holstein and Hamburg. Guidebook. - Mitt. Dtsch. Bodenk. Ges. 51.
- BLUME, H.-P., BEYER, L., PETERS, M. & C. G. SCHIMMING, 1989: Umweltschonende Bodennutzung in der Landwirtschaft. - Schriftenreihe Agrarw. Fak. Uni Kiel 71: 33-47.
- DRISCOLL, C. T., 1984: A procedure for fractionation of aqueous Aluminium in dilute acid waters. - Int. J. Environ. Anal. Chem. 16: 267-283.
- FIEDLER, H. J. & S. D. THAKUR, 1984: Der Schwefelhaushalt von Fichtenökosystemen und bewaldeten Wassereinzugsgebieten. - Archiv Naturschutz Landw. Forsch. 26: 177-192.
- FRANK, U., 1987: Aluminiumformen in sauren Waldböden Nordwestdeutschlands und Al-Anreicherung in Fein- und Schwachwurzeln von Waldbäumen. - Mitt. Dtsch. Bodenk. Ges. 55/I: 321-326.
- KREUTZER, K., 1989: Änderungen im Stickstoffhaushalt der Wälder und die dadurch verursachten Auswirkungen auf die Qualität des Sickerwassers. - In: DVWK (Ed.): DVWK-Mitt. 17: 121-132.
- MITCHELL, M. J. & J. P. NAKAS (Eds.), 1986: Microfloral and Faunal Interactions in Natural and Agro-Ecosystems. - Nijhoff and Junk Publishers, Dordrecht, Netherlands.
- NAIR, V. D. P. & J. PRENZEL, 1978: Calculations of equilibrium Concentrations of Mono- and Polynuclear Hydroxy-Aluminium Species at different pH and total Aluminium Concentrations. - Z. Pflanzenernähr. Bodenk. 141: 741-751.
- NÄTSCHER, L. & U. SCHWERTMANN, 1985: Aluminiumformen in Auflagehorizonten saurer Waldböden. - Mitt. Dtsch. Bodenkundl. Ges. 43/I: 435-439.
- PETERS, M., 1991: Nutzungseinfluß auf die Stoffdynamik schleswig-holsteinischer Böden-Wasser-und Stoffdynamik. - Schriftenr. Inst. Pflanzenernähr. Bodenk. Uni Kiel 8.
- ROST-SIEBERT, K., 1985: Untersuchungen zur H- und Al-Ionen Toxizität an Keimpflanzen von Fichte (*Picea abies*, Karst.) und Buche (*Fagus silvatica*, L.) in Lösungskultur. - Diss. Uni Göttingen.
- SCHLICHTING, E. & H.-P. BLUME, 1966: Bodenkundliches Praktikum. - Parey, Hamburg.
- SCHULZE, E.-D., LANGE, O. L. & R. OREN (Eds.), 1989: Forest Decline and Air Pollution. - Springer, Heidelberg.
- SZEGI, J., 1988: Cellulose Decomposition and Soil Fertility. - Akadémiai Kiadó, Budapest.
- ULRICH, B., MAYER, R. & P. K. KHANNA, 1979: Deposition von Luftverunreinigungen und ihre Auswirkungen in Waldökosystemen im Solling. - Schriftenr. Forstl. Fak. Univ. Göttingen Nr. 58, Sauerländer, Frankfurt.
- ULRICH, B. & E. SUMNER (Ed.), 1991: Soil Acidity. - Springer, Berlin.
- UNGER, H., 1960: Der Zellulosetest, eine Methode zur Ermittlung der zellulolytischen Aktivität des Bodens in Feldversuchen. - Z. Pflanzenernähr. Bodenk. 91: 44-52.
- VAN GENUCHTEN, N. T., 1980: A closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils. - Soil Sci. Soc. Am. J. 44: 892-898.

Addresses

- L. Beyer, H.-P. Blume,
M. Peters, B. Henß
Institut für Pflanzenernährung und Bodenkunde
Universität Kiel
Olshausenstraße 40-60
2300 Kiel 1
- U. Irmel
Forschungsstelle für Ökosystemforschung und Ökotechnik
Universität Kiel
Olshausenstraße 40-60
2300 Kiel 1

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